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13. ABSTRACT *(Maximum 200 words)*

The purpose of this study was to validate a shortened (11-item) electronic version of the 67-item paper and pencil Environmental Symptoms Questionnaire (ESQ-III) to assess acute mountain sickness (AMS). Thirty-four volunteers (means ±SE; 28±1 yrs; 74±2 kg) were given both the paper and pencil and electronic version of the ESQ (IPAQ 5550, Hewlett Packard, Palo Alto, CA) to complete one after the other at residence altitude (RA), and after 24-h (PP24), 48-h (PP48), and 72-h (PP72) exposure to 4300 m on the summit of Pikes Peak (PP). The AMS-Cerebral (AMS-C) weighted factor score was calculated from responses to the same 11 items for each version of the ESQ. If AMS-C was ? 0.7 then the individual was classified as having AMS. There were no differences in the incidence of AMS between the paper and pencil and electronic versions of the ESQ at RA (0% vs. 0%), PP24 (35% vs. 38%), PP48 (26% vs. 26%), and PP72 (18% vs. 18%). There were no differences in the severity of AMS between the paper and pencil and electronic versions of the ESQ at RA (0.05±0.01 vs. 0.03±0.01), PP24 (0.85±0.16 vs. 0.80±0.16), PP48 (0.61±0.15 vs. 0.58±0.15), and PP72 (0.34±0.09 vs. 0.35±0.09). The relationships between the incidence of AMS calculated from the two version of the ESQ at RA (k=0.90;p=0.01), PP24 (k=0.90;p=0.01), PP48 (k=0.91;p=0.01) and PP72 (k=0.92;p=0.01) were significant. The relationships between the severity of AMS calculated from the two versions of the ESQ at RA (r=0.43;p=0.01), PP24 (r=0.92;p=0.0001), PP48 (r=0.82;p=0.0005) and PP72 (r=0.95;p=0.0001) were significant. Our findings suggest that the shortened (11-item) electronic version can be substituted for the 67-item paper and pencil version of the ESQ to assess AMS at 4300 m.

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USARIEM TECHNICAL REPORT T07-03

VALIDATION OF A SHORTENED ELECTRONIC VERSION OF THE ENVIRONMENTAL SYMPTOMS QUESTIONNAIRE

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EXECUTIVE SUMMARY

The Environmental Symptoms Questionnaire (ESQ-III) is a validated 67-item paper and pencil questionnaire utilized to assess symptoms of acute mountain sickness (AMS) in individuals exposed to altitude. Problems encountered with administering the ESQ-III include 1) lengthy time to complete, 2) inaccurate answers due to boredom, 3) intentional or unintentional skipping of questions and 4) multiple answers to the same question due to stray marks. In order to eliminate these problems, a shortened (11-item), electronic version of the ESQ was developed that could be administered on a hand-held computer (IPAQ 5550, Hewlett Packard, Palo Alto, CA). The purpose of this study was to validate the shortened electronic version of the ESQ to assess AMS. Thirty-four volunteers (28±1 yrs; 74±2 kg; 174±3 cm; means ±SE) were given both the paper and pencil and the shortened electronic version of the ESQ to complete one after the other at residence altitude (RA), and after 24-h (PP24), 48-h (PP48), and 72-h (PP72) exposure to 4300 m on the summit of Pikes Peak (PP). The AMS-Cerebral (AMS-C) factor score was calculated from responses to the same 11 items for each version of the ESQ. If the AMS-C score was ≥0.7 then the individual was classified as having AMS. There were no differences in the severity of AMS between the paper and pencil and electronic versions of the ESQ at RA (0.05±0.01 vs. 0.03±0.01), PP24 (0.85±0.16 vs. 0.80±0.16), PP48 (0.61±0.15 vs. 0.58±0.15), and PP72 (0.34±0.09 vs. 0.35±0.09). There were also no differences in the incidence of AMS between the paper and pencil and electronic versions of the ESQ at RA (0% vs. 0%), PP24 (35% vs. 38%), PP48 (26% vs. 26%), and PP72 (18% vs. 18%). The relationships between the severity of AMS calculated from the two versions of the ESQ at RA (r=0.43;p=0.01), PP24 (r=0.92;p=0.0001), PP48 (r=0.82;p=0.0005), and PP72 (r=0.95;p=0.0001) were highly significant. The relationships between the incidence of AMS calculated from the two versions of the ESQ at RA (k=0.90;p=0.01), PP24 (k=0.90;p=0.01), PP48 (k=0.91; p=0.01), and PP72 (k=0.92; p=0.005) were also highly significant. Our findings suggest that the shortened (11-item) electronic version can be substituted for the 67-item paper and pencil version of the ESQ in order to assess the severity and incidence of AMS at 4300 m.

INTRODUCTION

Acute Mountain Sickness (AMS) is a syndrome that is characterized by headache, insomnia, anorexia, nausea, dizziness, and fatigue, but without abnormal neurological findings (11, 22). The severity and incidence of AMS is primarily related to the initial altitude, the rate of ascent, the altitude reached, and the duration of exposure to altitude (9, 13, 16, 21, 30). Additional factors that affect the severity and incidence of AMS are the degree of hypoxemia (2, 5, 10, 18), level of physical exertion performed (8, 24), individual susceptibility (25, 31), and degree of prior altitude acclimatization (12, 15). Symptoms of AMS typically become evident in the first few hours of altitude exposure and reach peak severity in 24 to 48 h (22). The chief significance of AMS is that people rapidly exposed to altitude may be completely incapacitated in the first few days at altitude (22). Additionally, in a few individuals, AMS may progress to life-threatening high-altitude cerebral edema or high-altitude pulmonary edema, where evacuation is required.

The ability to measure AMS accurately, therefore, is critically important in individuals ascending to high altitudes for work or recreation. AMS is traditionally measured using a validated 67-item paper and pencil Environmental Symptoms Questionnaire (ESQ-III) (28). The AMS-Cerebral (AMS-C) factor score is calculated from answers to 11 of the 67 questions to assess the severity of AMS. If the AMS-C score is $\geq$0.7 then the individual is classified as having AMS (e.g., sick versus not sick). Despite its usefulness in assessing AMS, problems encountered with administering the ESQ-III include: 1) lengthy time to complete, 2) inaccurate answers due to boredom, 3) intentional or unintentional skipping of questions and 4) multiple answers to the same question due to stray marks. Although a shorter five-item paper and pencil questionnaire (Lake Louise (LL) AMS Scoring System) exists (23) and has been validated against the ESQ-III (17, 29), the LL questionnaire tends to overestimate AMS compared to the ESQ-III (1, 27). In order to eliminate administrative problems with the paper and pencil version of the ESQ-III and overestimation of AMS by the LL questionnaire, a shortened (11-item), electronic version of the ESQ was developed that could be administered on a hand-held computer. The purpose of this study was to validate the shortened electronic version of the ESQ to assess AMS.

METHODS

SUBJECTS

Thirty-four sea-level (n=17) and moderate-altitude (n=17) residents (27 men, 7 women) with a mean (±SE) age, body weight, and height of 28±1 yr, 74±2 kg, 174±3 cm, respectively, completed this study. Sea-level and moderate-altitude residents were recruited in order to measure a wide range of AMS during exposure to 4300 m. The sea-level residents were recruited from the Palo Alto, CA area (15 m) while the moderate-altitude residents were recruited from the Colorado Springs, CO area (~2000 m). All volunteers received medical examinations, and none had any condition warranting exclusion from the study. All tested within normal ranges for pulmonary

function. All had normal hemoglobin concentration and serum ferritin levels. Each gave written and verbal acknowledgment of their informed consent and was made aware of their right to withdraw without prejudice at any time. Investigators adhered to the policies for protection of human subjects as prescribed in Army Regulation 70-25, and the research was conducted in adherence with the provisions of 45 CFR Part 46.

PROTOCOL

Design

This study utilized a two (version) x four (condition) repeated-measures counter-balanced experimental design. The two ESQ test versions were defined as paper and pencil and electronic. The four test conditions were defined as residence altitude (RA), and following 24-h (PP24), 48-h (PP48), and 72-h (PP72) exposure to 4300 m on the summit of Pikes Peak (PP). All volunteers were rapidly ($\leq$4 h) exposed to 4300 m after measurements at their RA. Each test volunteer completed each of the two versions of the ESQ one right after the other in a counterbalanced fashion (e.g., half completed the paper and pencil version first, while half completed the electronic version first) for each of the four test conditions.

Altitude-Illness Assessment

Severity and incidence of AMS symptoms were determined from information gathered using both the 67-item paper and pencil and the shortened (11-item) electronic ESQ. The paper and pencil ESQ is a self-reported, 67-item inventory designed to quantify symptoms induced by altitude and other stressful environments (28). Symptom severity is self-rated on a scale of 0 to 5, with a score of “0” indicating the absence of symptoms and “5” indicating maximum intensity of the symptoms. A weighted average of cerebral symptoms (headache, lightheaded, dizzy) designated “AMS-C” was calculated from 11 of the 67 items to assess the severity of AMS. AMS was judged to be present if an individual’s AMS-C score was $\geq$0.7. The effectiveness of AMS-C scores in identifying individuals with AMS has been previously reported and validated (28). The shortened electronic ESQ consisted of the same 11 items from the paper and pencil ESQ that are used to determine AMS-C, and was administered on a hand-held computer (IPAQ 5550, Hewlett Packard, Palo Alto, CA). The incidence of AMS (%) for both versions of the ESQ was defined as the number of test volunteers who achieved or exceeded the AMS-C criterion score value at each time point divided by the total number of test volunteers measured at that time point.

STATISTICS

A two (version) x four (condition) repeated-measures ANOVA and Cochran’s Q was used to analyze differences in the severity and incidence of AMS, respectively, between test versions and test conditions. Pearson-product correlation coefficients and kappa statistics were calculated to determine the relationships between the severity and incidence of AMS-C scores, respectively, between the two versions of the ESQ in each of the four test conditions. The AMS-C difference scores between the two test versions (paper and pencil – electronic) were calculated in each of the four test conditions and

compared to zero as well as to each other. Individual difference scores of zero would indicate that there were no differences between the two ESQ test versions, while negative difference scores represent overestimations of AMS-C by the electronic version and positive difference scores indicate underestimations of AMS-C by the electronic version. The limits of agreement were calculated for each of the difference scores in each of the test conditions and Bland-Altman plots were constructed (3). Individual difference scores that have a tight prediction interval around zero indicate greater agreement between the two versions of the ESQ. Significant main effects and interactions were analyzed using Tukey's least significant difference test. Statistical significance was set at $P < 0.05$. All data are presented as means ± SE.

RESULTS

ALTITUDE-ILLNESS ASSESSMENT

The AMS-C scores measured using the paper and pencil and electronic versions of the ESQ at RA (0.05±0.01 vs. 0.03±0.01), PP24 (0.85±0.16 vs. 0.80±0.16), PP48 (0.61±0.15 vs. 0.58±0.15), and PP72 (0.34±0.09 vs. 0.35±0.09) were not significantly different in any of the four test conditions. The incidence of AMS using the paper and pencil and electronic versions of the ESQ at RA (0% vs. 0%), PP24 (35% vs. 38%), PP48 (26% vs. 26%), and PP72 (18% vs. 18%) were also not significantly different in any of the four test conditions. The relationships between the severity of AMS calculated from the two versions of the ESQ at RA ($r=0.43; p=0.01$), PP24 ($r=0.92; p=0.0001$), PP48 ($r=0.82; p=0.0001$), and PP72 ($r=0.95; p=0.0001$) were highly significant (Figure 1). The relationships between the incidence of AMS calculated from the two versions of the ESQ at RA ($k=0.90$; $p=0.01$), PP24 ($k=0.90$; $p=0.01$), PP48 ($k=0.91$, $p=0.01$) and PP72 ($k=0.92$, $p=0.005$) were also highly significant. The mean AMS-C difference scores (paper and pencil – electronic) in each of the four test conditions are plotted in Figure 2. The mean AMS-C difference scores were not significantly different from zero or from each other in any of the four test conditions. Bland-Altman plots for the individual AMS-C difference scores and limits of agreement (±2SD) in each of the four test conditions are presented in Figure 3. The level of agreement between the two versions of the ESQ at RA and PP72 was exceptional with 95% prediction intervals that were within ±0.18 and ±0.42 from zero, respectively. The level of agreement between the two versions of the ESQ at PP24 and PP48 was moderate with 95% prediction intervals that were within ±0.87 and ±1.09, respectively from zero.

Figure 1. Pearson-product correlation coefficients for the relationship between AMS-C measured from the paper and pencil and electronic versions of the Environmental Symptoms Questionnaire at residence altitude (RA) and after 24-h (PP24), 48-h (PP48), and 72-h (PP72) exposure to 4300 m on the summit of Pikes Peak (PP)

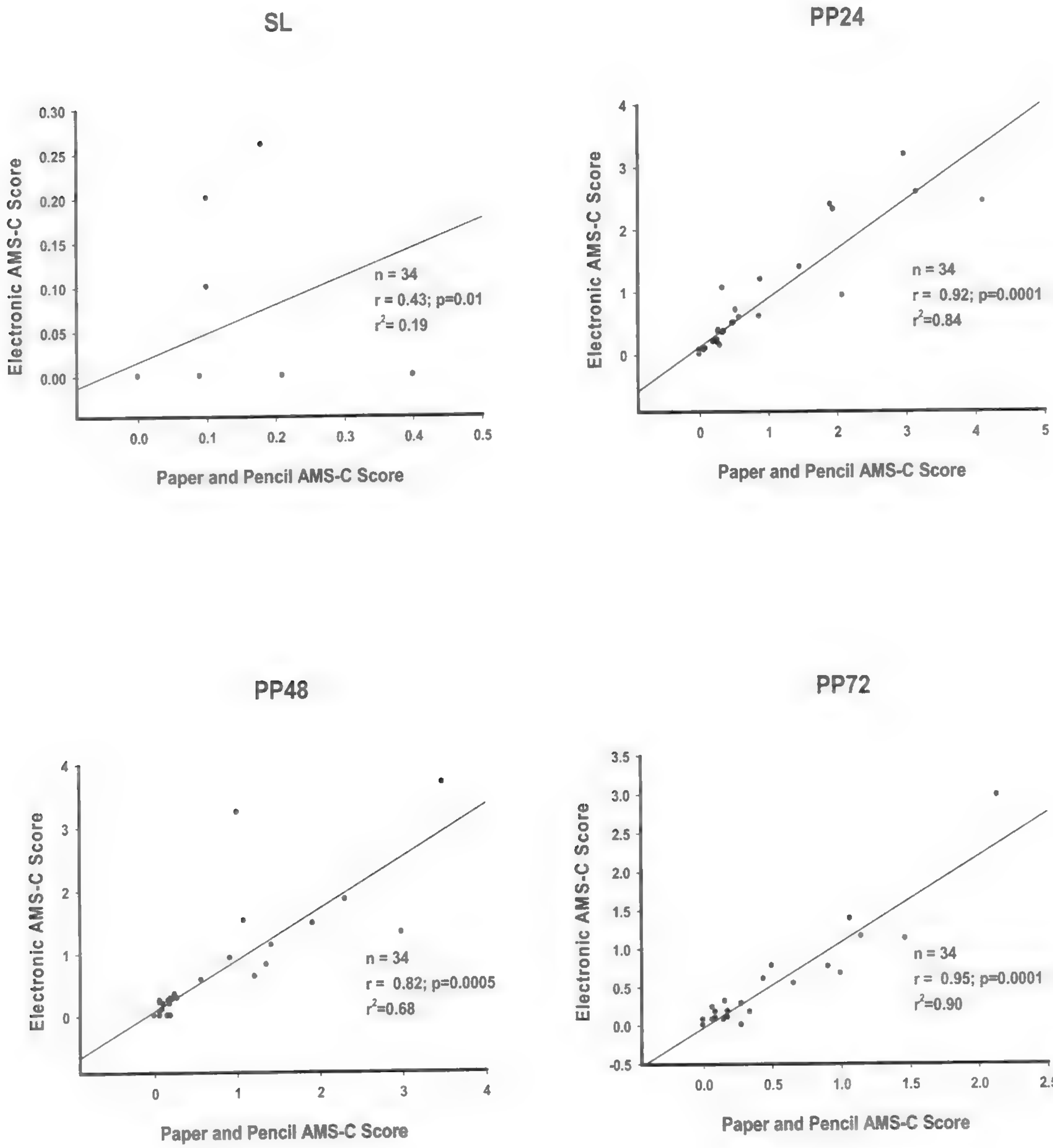


Figure 2. Mean AMS-C difference scores at residence altitude (RA) and after 24-h (PP24), 48-h (PP48), and 72-h (PP72) exposure to 4300 m on the summit of Pikes Peak (PP)

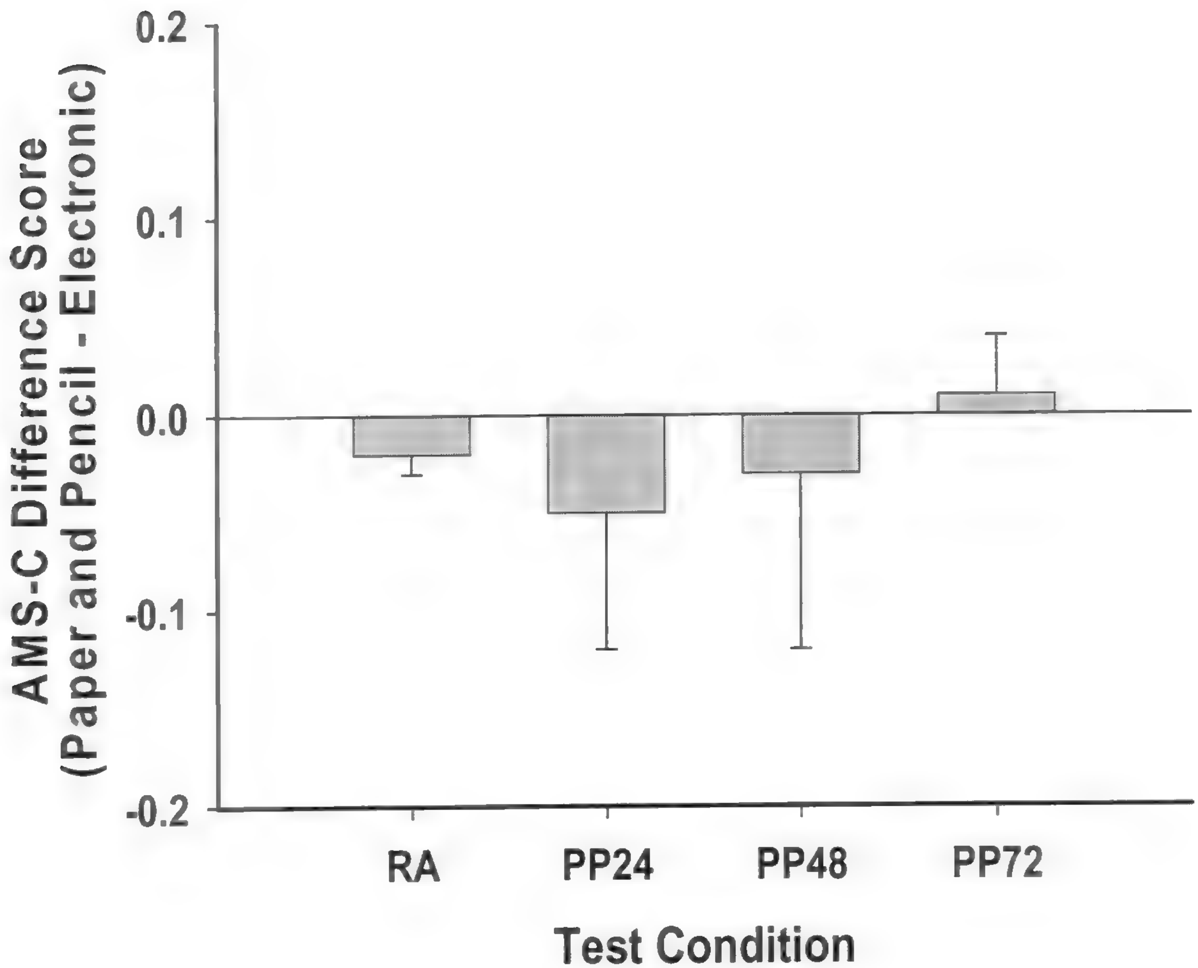
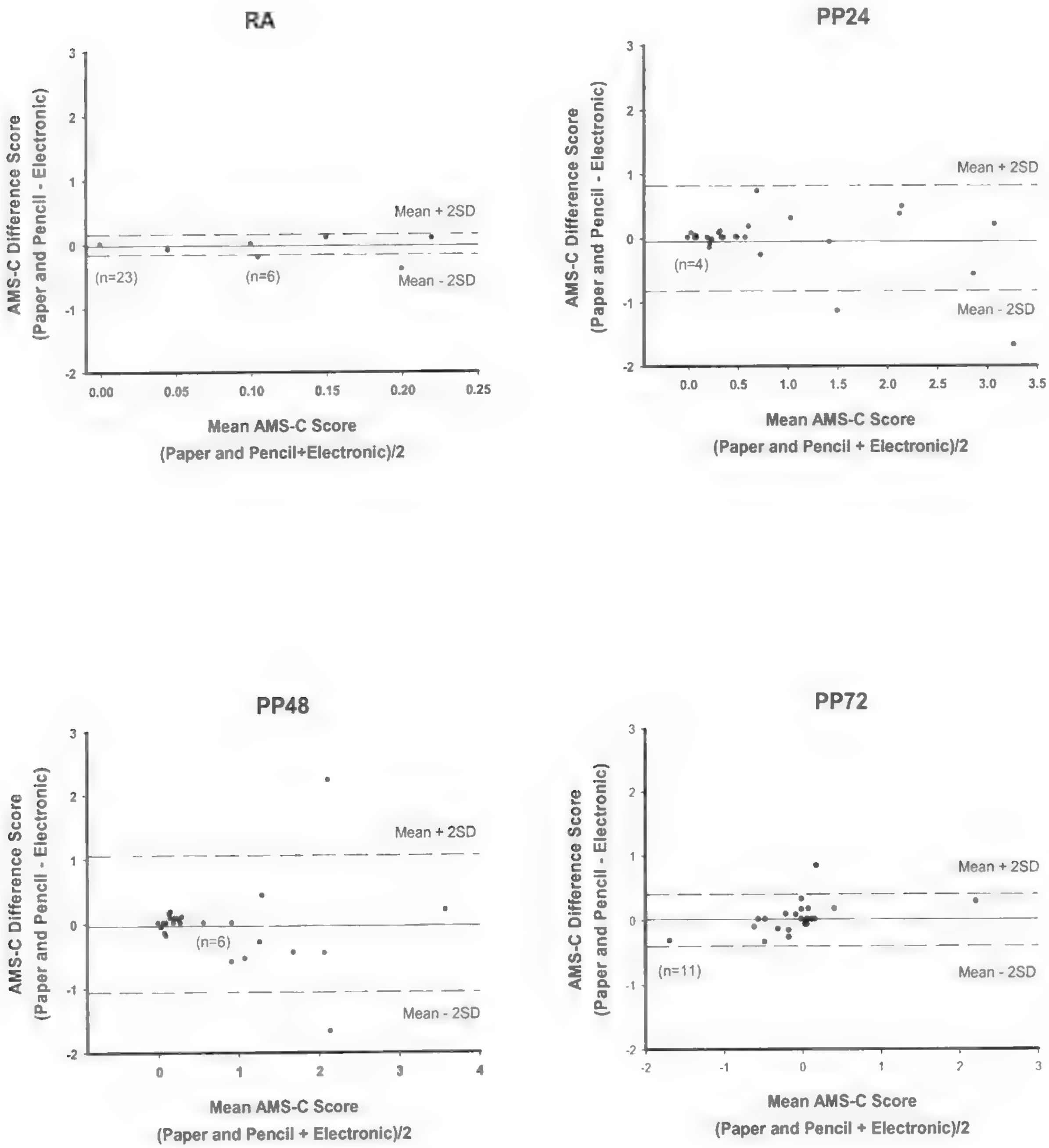


Figure 3. Bland-Altman plots for the mean AMS-C difference scores at residence altitude (RA) and following 24-h (PP24), 48-h (PP48), and 72-h (PP72) exposure to 4300 m on the summit of Pikes Peak (PP)



DISCUSSION

The purpose of this study was to validate the shortened electronic version of the ESQ to assess AMS. Our major findings were the following: 1) neither the severity nor the incidence of AMS differed between the paper and pencil and electronic versions of the ESQ in any test condition, 2) the relationships between both the severity and incidence of AMS measured by the two versions of the ESQ were highly significant, and 3) the AMS-C difference scores between the two versions of the ESQ in all four test conditions were not significantly different from zero or from each other. These findings suggest that the shortened (11-item) electronic version can be substituted for the 67-item paper and pencil version of the ESQ in order to assess the severity and incidence of AMS at 4300 m.

Assessment of AMS is a critical component in most studies conducted at high altitude. It was recognized by leaders in the field that the 67-item ESQ-III was lengthy and cumbersome to use in high altitude research. Thus, a consensus group proposed the 5-item self-assessment Lake Louise (LL) scoring system in 1991, which was revised in 1993 (23). This scoring system has been widely used since that time but our laboratory (27) and others (1) have found that it tends to overestimate the incidence of AMS compared to the ESQ, possibly due to the detection of AMS at an earlier stage or in a milder form. As such, the need remained for a shortened and less cumbersome method for assessing the incidence and severity of AMS that directly compares to the results obtained from the 67-item paper and pencil ESQ. Thus, a shortened (11-item), electronic version of the ESQ was developed that could be administered on a hand-held computer.

Whenever a questionnaire is shortened or the mode of delivery is altered, it is critical to validate whether these changes affect the values of the measurement. Although the AMS-C value is calculated from only 11 of the 67 items contained in the paper and pencil ESQ and these same 11 items were utilized in the shortened electronic version of the ESQ, it was unknown whether a difference in the number of items would have any effect on AMS-C values. It was also unknown whether changing the mode of delivery to a handheld computer, such that each question had to be answered before proceeding to the next question, would affect AMS-C values. Given the results of this study, it does not appear that fewer items or changing the mode of delivery affected AMS-C values in any way. The fact that AMS-C difference scores were not significantly different in any test condition also suggests that the shortened electronic version of the ESQ can be used at any time point at altitude.

The only concern with our analysis of AMS-C values measured by both the paper and pencil and electronic ESQ was the wide prediction intervals at PP24 and PP48. However, close examination of the Bland Altman plots at PP24 and PP48 (Figure 3) suggest that the mean AMS-C points along the x-axis in the range between 0.5 and 1.0 (the threshold level for AMS-C is $\geq$0.7) are not widely dispersed. Thus, the agreement between the two versions of the ESQ is likely much higher in this critical range than what is reported for the overall range of points. It is only when the AMS-C

values get larger and farther away from typical mean values of AMS-C that the points on the plot become more widely dispersed.

Administering the questionnaire by computer likely insures greater accuracy because the possibility of leaving questions unanswered or making stray marks does not exist. In addition, by shortening the time it takes to answer the questionnaire, volunteer motivation is more likely to remain high such that volunteers will actually take the time to read each question instead of just randomly circling a number. In other studies that have compared paper and pencil administration versus computer administration of a health questionnaire, no differences in the validity of answers have been reported (4, 6, 14, 19, 20). In fact, these studies reported that 69% to 82% of the users preferred computer administration of the test (4, 6) even when half of the subjects reported no computer experience. In addition, one study reported that the built-in requirement to answer questions in the computer version as well as the shortened administration time increased both accuracy and compliance (19).

CONCLUSIONS

In conclusion, the shortened electronic version of the ESQ represents a valid method for assessing the severity and incidence of AMS during 72-h of exposure to 4300 m.

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